RESEARCH MEMORANDUM

FUNDAMENTAL FLAME VELOCITY, HEAT OF COMBUSTION, AND SPONTANEOUS IGNITION TEMPERATURE OF DIMETHYLAMINODIBORANE

By Robert R. Hibbard and Gordon L. Dugger

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
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SUMMARY

The following properties were determined for a sample of dimethylaminodiborane:

(1) Maximum fundamental flame velocity for fuel and air at 35° C, 115±5 centimeters per second.

(2) Net (lower) heat of combustion of liquid fuel to gaseous nitrogen, carbon dioxide, and water, and to solid boric oxide, 19,225±100 Btu per pound.

(3) Spontaneous ignition temperature, 240°±10° F.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, the NACA is participating in a project aimed at the discovery and evaluation of certain high energy fuels, Project Zip. A part of the work that the NACA will perform in this project is the determination of the fundamental flame velocities and possibly other combustion properties of fuel samples submitted by companies participating in the project as contractors to the Bureau of Aeronautics, Department of the Navy.

The first of these fuels to be received was a sample of dimethylaminodiborane prepared by the Callery Chemical Company. Fundamental flame velocities, heat of combustion, and the spontaneous ignition temperature have been determined for this material. Although the precision of measurement of these properties has not been equal to that obtained for hydrocarbons, this report has been prepared to make the preliminary data available as soon as possible.

PROCEDURE AND RESULTS

Fundamental Flame Velocity

Flame velocities were measured by a Bunsen burner method for several fuel-air ratios at atmospheric pressure (745 mm Hg) and room temperature (nonheated, oil-jacketed system, 32° to 35.5° C). The apparatus was the same as that described in reference 1. The liquid dimethylaminodiborane was fed at a constant rate to a glass capillary tee where it was vaporized by and mixed with a turbulent air stream. The mixture passed through a plenum chamber and into the 4.65 millimeter stainless steel burner tube. The preflame residence time for the mixture was approximately 8 seconds, with a stream flow Reynolds number of 2000 in the burner tube. Flame velocities were measured from the outside edge of the schlieren image (knife-edge horizontal from top) of the inner Bunsen cone using a total-area method as described in reference 1.

The data are plotted in figure 1, from which it is seen that for an average temperature of 34° C a maximum flame velocity of 115±5 centimeters per second occurs at an equivalence ratio of approximately 1.25, The scatter of the data is due in part to the fact that as the flame was allowed to sit on the burner a glassy ring of B_2O_3 was built up at the burner tube lip. This ring had a height of 1 millimeter in the worst case. The solid symbols in figure 1 represent flame velocities computed from flames visible above the B_2O_3 ring. However, since the inside wall of the B_2O_3 ring was slightly divergent in cross section, the true base of the flames may have extended down into the ring slightly. As limiting cases, the equivalent flames extending to the burner port were recalculated and shown by the open symbols for each point where a B_2O_3 ring was present. The true flame velocity for a given equivalence ratio should therefore lie between the solid and open symbols.

Heat of Combustion

A Parr oxygen bomb calorimeter was used with the modifications described in reference 2. The sample, sealed in a soft glass capsule, was ignited by the fuse wire which also broke the capsule and released the fuel into a specially designed crucible. After combustion the gaseous combustion products were flushed through ascarite and the carbon dioxide formed on burning was so determined. Boron was determined in the nonvolatile combustion products using the method described in reference 3.

The results from three determinations of the heat of combustion of dimethylaminodiborane and the analyses of the combustion products are given in table I. The heats of combustion are the gross values determined

directly in the bomb with carbon dioxide, liquid water, and solid meta boric acid as the combustion products and with part of the boric acid dissolved in the water which was present in the bomb. Values of 11.78±0.06 kilocalories per gram or 21,210±100 Btu per pound are shown for this gross heating value. The determined percent carbon averaged slightly above the theoretical value for the pure compound, but the difference is within the expected experimental accuracy. The determined percent boron ran well below the theoretical value and may indicate an impurity in the dimethylaminodiborane.

The determined gross heating value from table I was rounded off to 11.80 kilocalories per gram equivalent to 834.9 kilocalories per mole or 21,240 Btu per pound. Net heating value was calculated by making the following corrections:

(1) Conversion from a constant volume process to a constant pressure process, a subtractive correction of 2.1 kilocalories per mole.

(2) Correction for the heat of hydration of boric oxide to metaboric acid and the heat of solution of part of the acid so formed, a subtractive correction of 17.6 kilocalories per mole.

(3) Correction for the latent heat of vaporization of the water formed during combustion, a subtractive correction of 1466 Btu per pound of dimethylaminodiborane.

With these corrections the net heat of combustion of liquid dimethylaminodiborane to gaseous nitrogen, carbon dioxide, and water and to solid boric oxide becomes 19,275 Btu per pound. For the case where liquid boric oxide is formed an additional correction for the heat of fusion of this oxide (ref. 4) must be subtracted. The net heat in this latter case is then 19,140 Btu per pound.

Spontaneous Ignition Temperature

This temperature was determined by a modified A.S.T.M. crucible method using the procedure described in reference 4. The fuel was drawn from nitrogen-blanketed serum vials using a hypodermic needle syringe and injected into the crucible. A spontaneous ignition temperature of 240°±10° F was so determined.

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National Advisory Committee for Aeronautics
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TABLE I. - GROSS HEATING VALUES, CARBON AND BORON ANALYSES FROM THREE HEAT OF COMBUSTION DETERMINATIONS

Experiment	Gross heating value		Analysis of combustion products	
	kcal/g	Btu/lb	Carbon, percent	Boron, percent
1	11.84	21,312	34.09	28.75
2	11.78	21,205	34.24	28.75
3	11.73	21,113	33.82	28.85
Average	11.78	21,210	34.05	28.78
Theoretical			33.95	30.58

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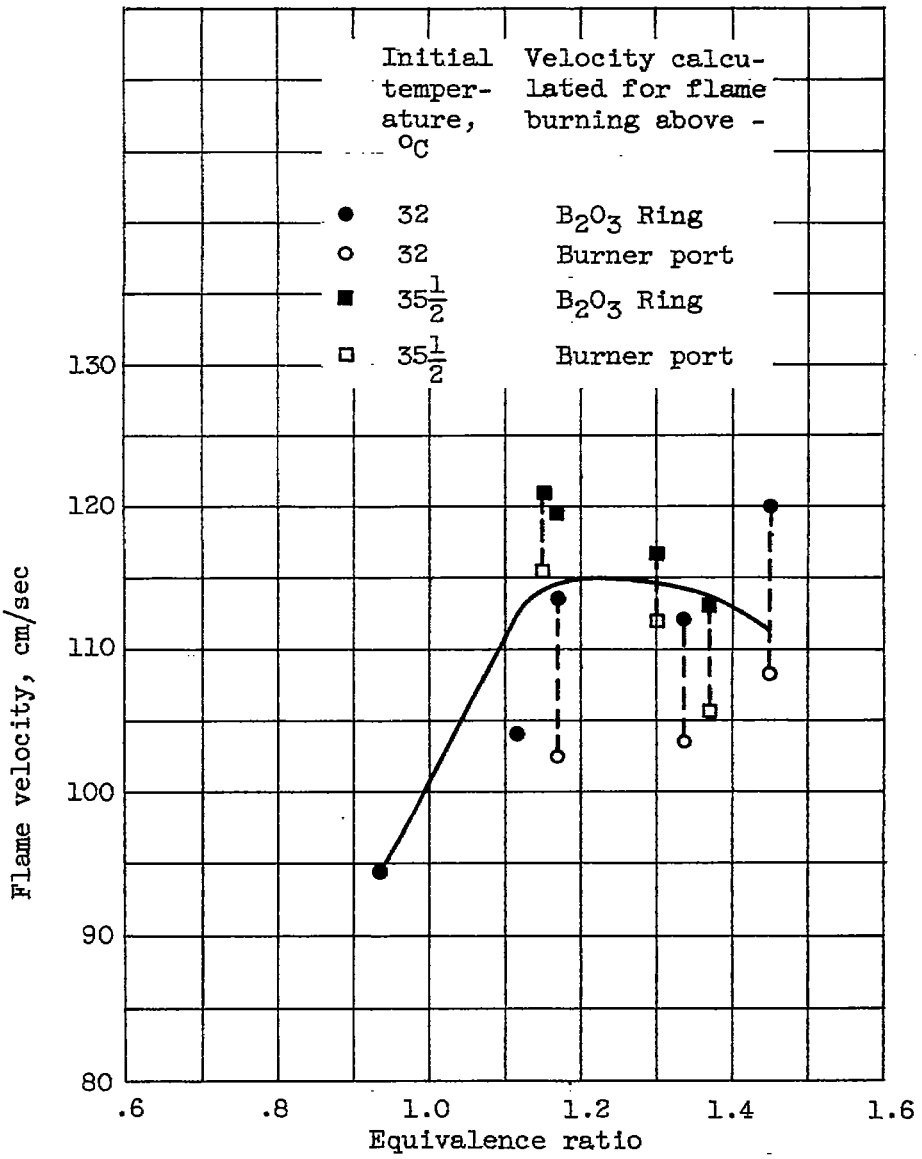

Figure 1. - Fundamental flame-velocity of dimethylaminodiborane in air.

NACA - Langley Field, Va.